Central Nervous System Monitoring During Operations on the Thoracic Aorta

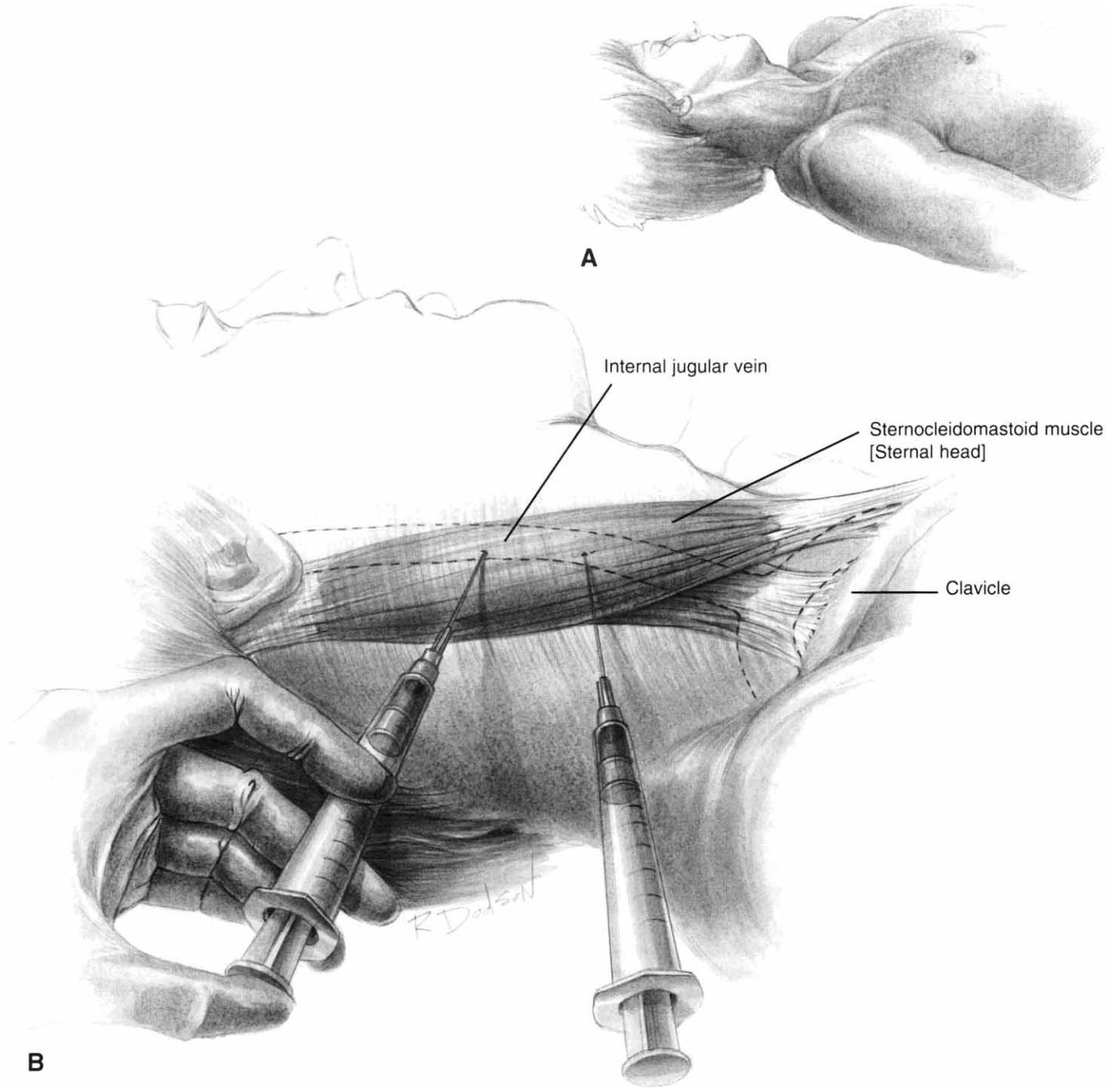
Jock N. McCullough, Jan D. Galla, M. Arisan Ergin, and Randall B. Griepp

Reparative procedures on the thoracic aorta often require interruption of the nutritive blood flow to the central nervous system. Recent technical advances in the surgical approach to the thoracic aorta have allowed for more extensive reconstruction, as outlined elsewhere in this issue. There remains, however, an incidence of severe neurological sequelae-stroke, *paraplegia*, *delirium*, and *persistent coma* associated with operations on the thoracic aorta. These complications are in part secondary to an imperfect system for neurological protection.

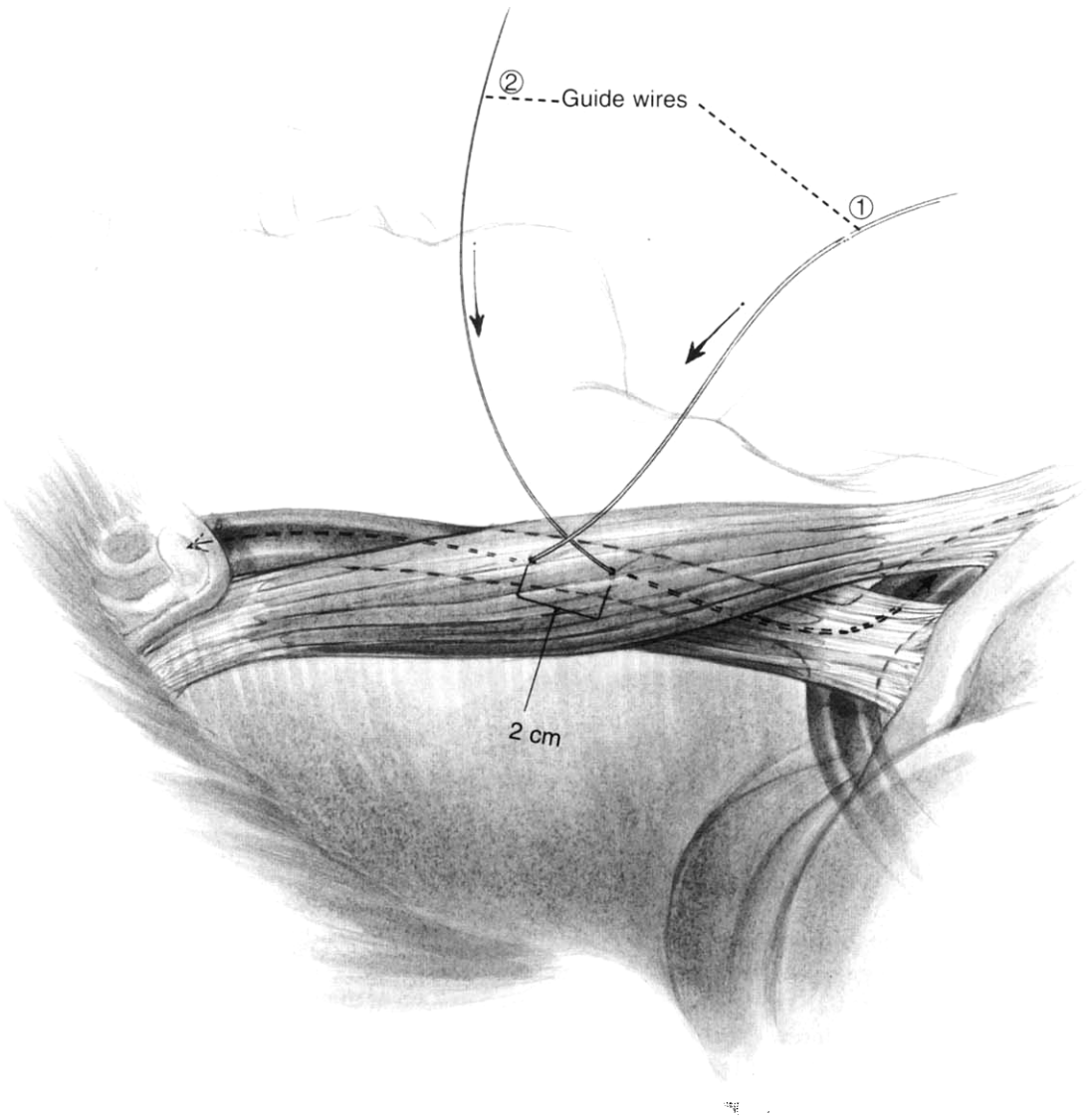
Our group has used profound hypothermia as the primary means of neuroprotection for operations requiring circulatory arrest.[1] Two fundamental issues with deep hypothermic circulatory arrest (DHCA) are the temperature level required for adequate protection and how to ensure that an appropriate level of cerebral metabolic suppression has been reached prior to DHCA. As will be detailed in the following figures, the use of the jugular bulb cerebral mixed venous saturation (JSAT) has become our preferred technique for monitoring cerebral metabolic rate prior to circulatory arrest.

The second portion of the figures details the use of somatosensory evoked potentials (SSEP) for monitoring of spinal cord function during operations on the descending thoracic aorta. The underlying hypothesis to our approach to the descending thoracic aorta is that the anterior spinal artery is actually a continuous network along the spinal cord with multiple segmental inputs.[2] Our group begins monitoring of the SSEPs just after anesthetic induction. The aorta is then mobilized sequentially in a cephalad to caudad direction. As each large pair of intercostal vessels is encountered, a large atraumatic but occlusive hemoclip is applied. After application of the clip, the SSEP is monitored for 5 to 10 minutes while further dissection proceeds. If there is no significant change in the SSEP pattern, the intercostal artery is sacrificed between medium permanent occlusive hemoclips. If there is a demonstrable change noted in the SSEPs, consideration of reimplantation of that intercostal artery is appropriate.

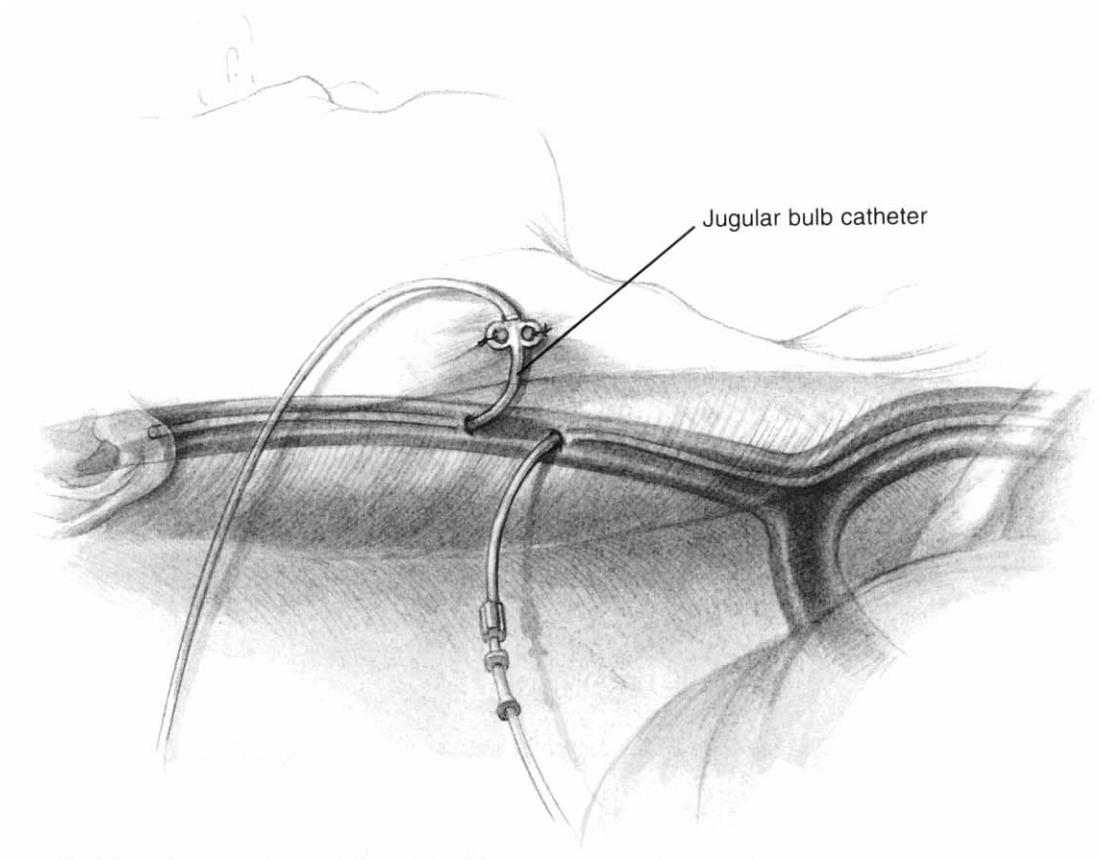
SURGICAL TECHNIQUE



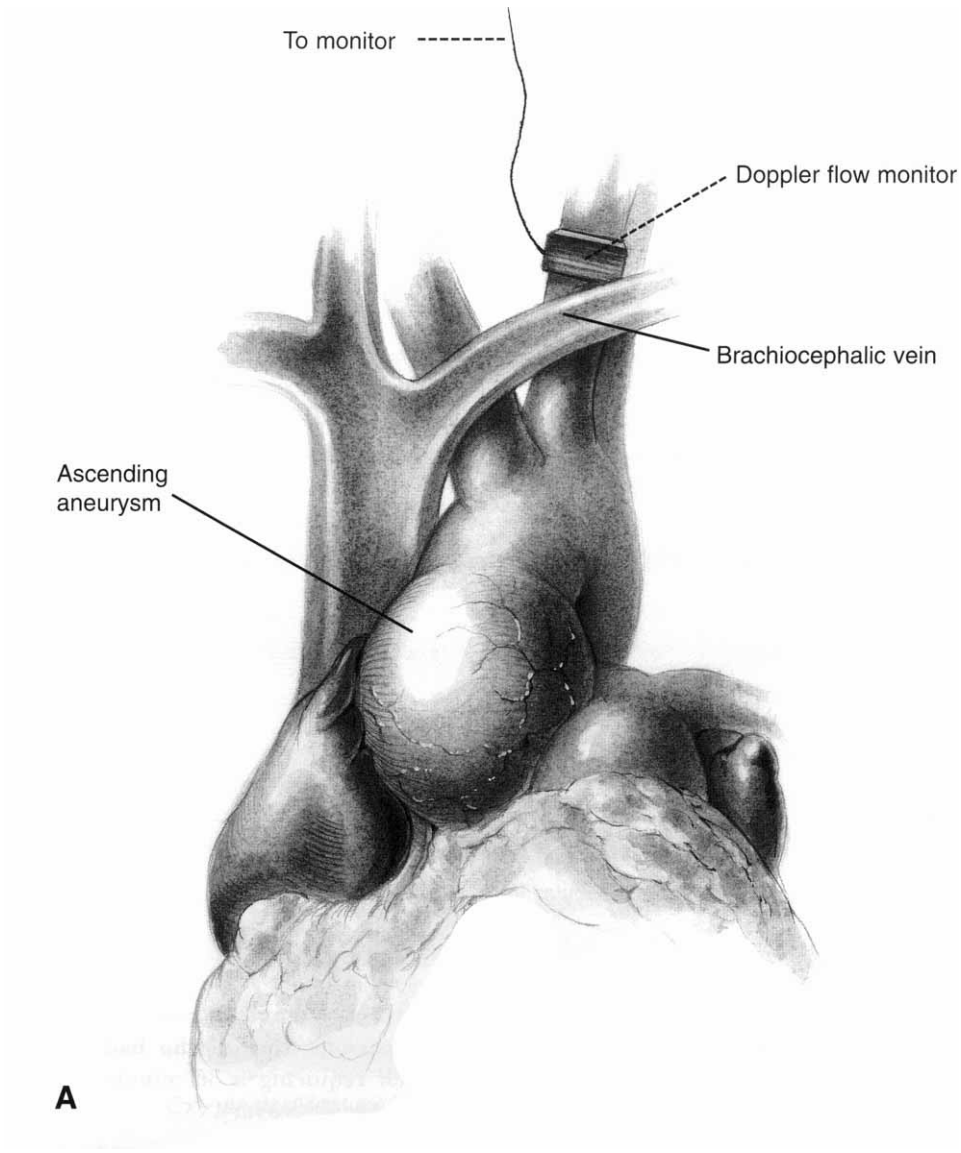
1 (A) Position of patient for insertion of pulmonary venous and jugular bulb monitoring lines. (B) A standard percutaneous approach is used to access the internal jugular vein. Two sequential venipunctures are required, each followed by guidewire placement. The sites should be separated by 1 to 2 cm.



2 The superior guide wire is directed cephalad for approximately 10 cm, or until any resistance is met. This guidewire will usually pass to the level of the mastoid process. The second wire is directed toward the central circulation as per routine for the placement of a pulmonary artery catheter.

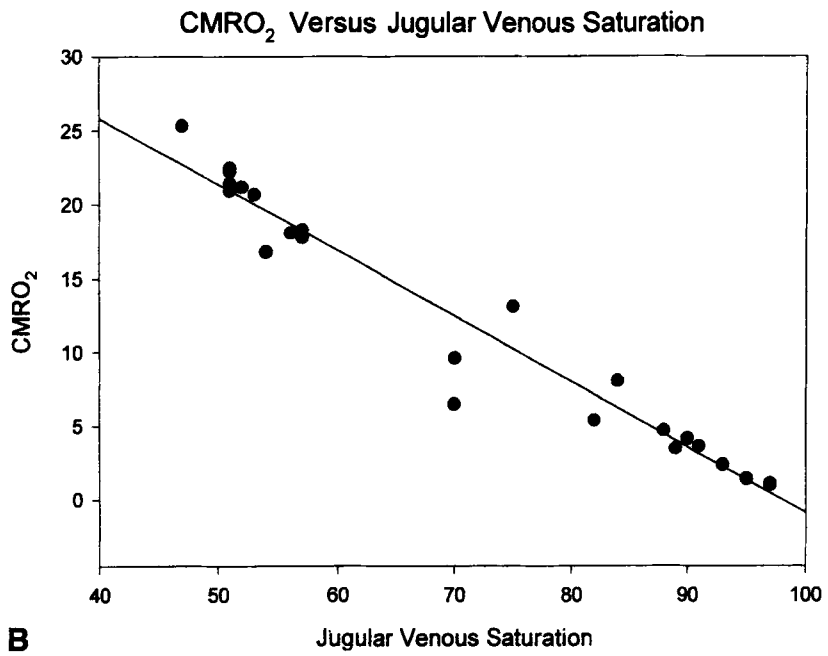


3 As per routine, a pulmonary artery catheter introducer sheath is placed via Seldinger technique over the caudad guide wire. A 20-gauge 20-cm catheter is then advanced over the cephalad guide wire toward the jugular bulb. The last 5 to 7 cm of the jugular bulb catheter is left outside of the skin incision to create a 180° curve to prevent kinking of the catheter. This step is particularly important during operations on the distal arch and descending aorta through a thoracotomy incision. Each catheter should then be sutured in place. Easy withdrawal of blood should be confirmed from the jugular bulb catheter. Further confirmation of proper placement can be accomplished by determination of a baseline oxygen saturation level. The finding of a jugular bulb saturation above 70% in an anesthetized patient at baseline should suggest the possibility of catheter malposition into either a facial or external jugular vein.

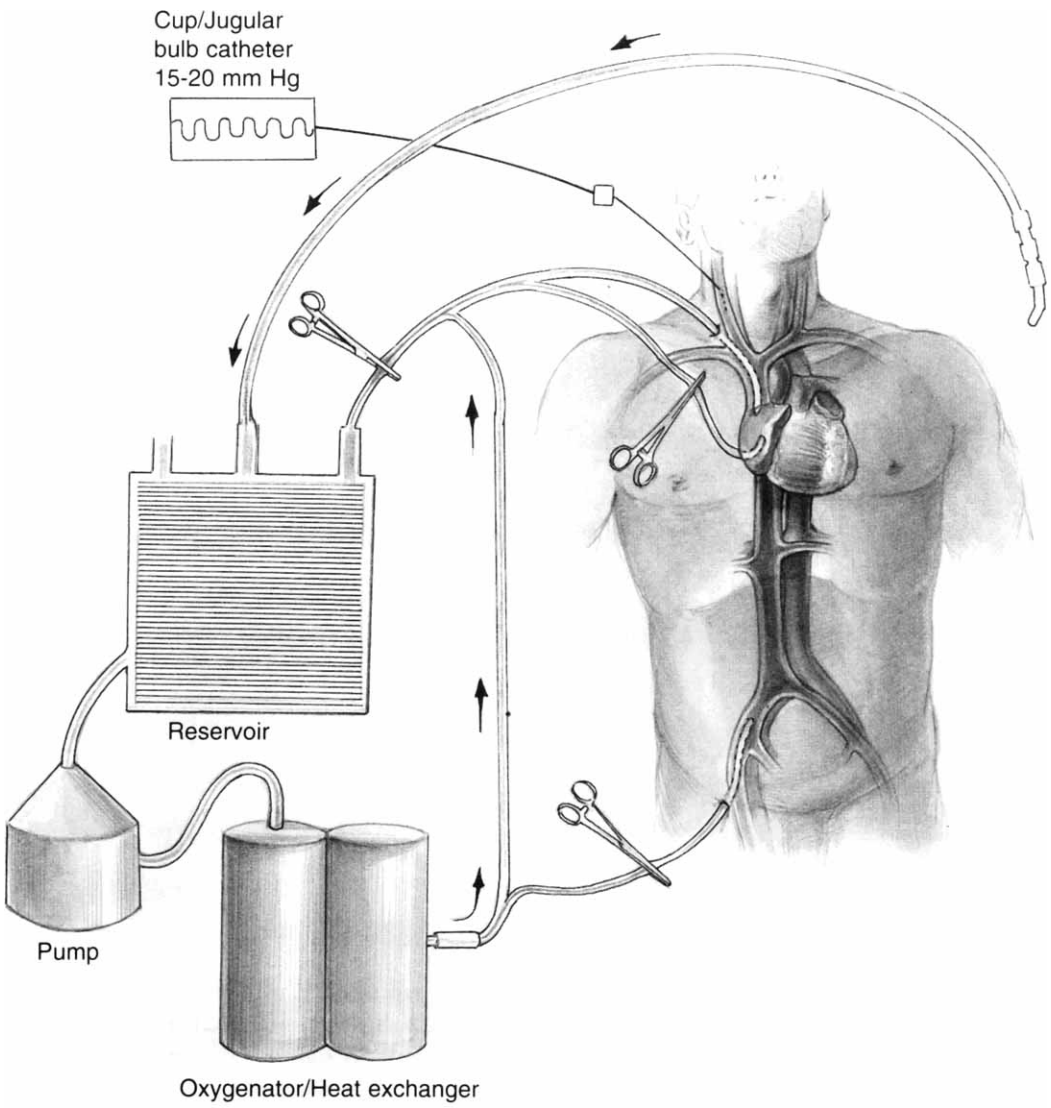


4 (A) The placement of a doppler flow probe on the left common carotid artery allows for an estimation of cerebral blood flow. If subsequent determinations are expressed as a proportion of the stable baseline cerebral blood flow (CBF), an estimate of the cerebral metabolic rate for oxygen ($CMRO_2$) can be determined with the following equation:

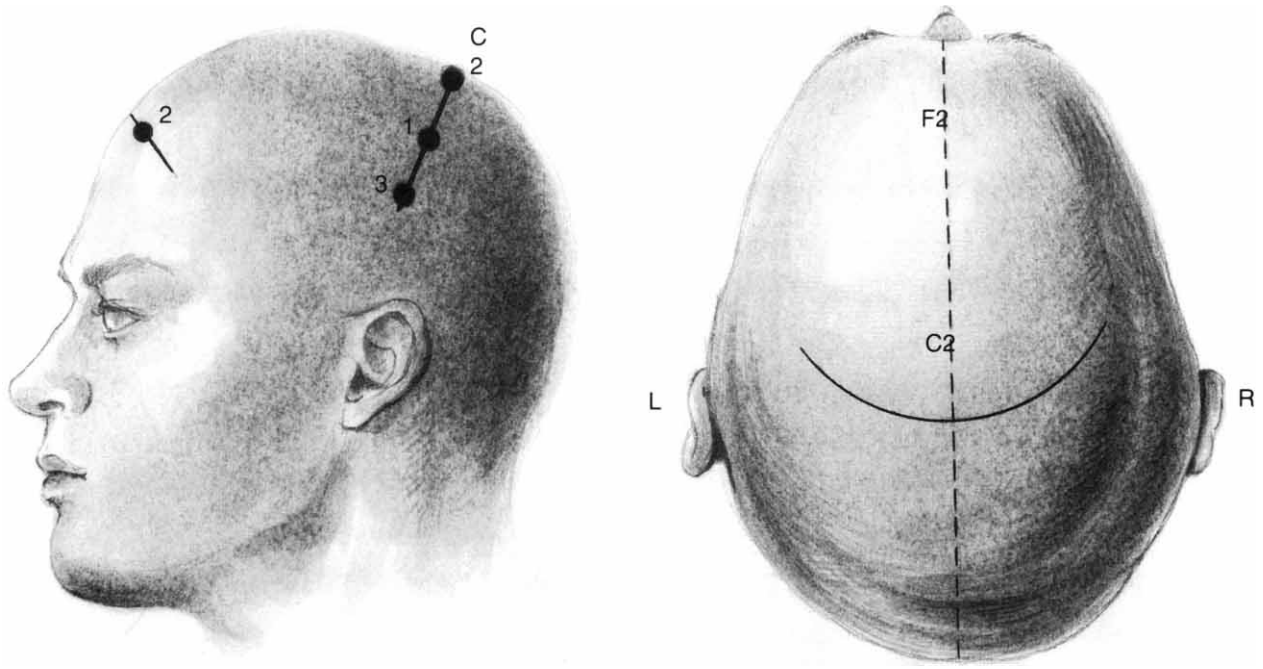
$$CMRO_2 = (CBF)(\text{cerebral arteriovenous oxygen content differences}) \div 100$$



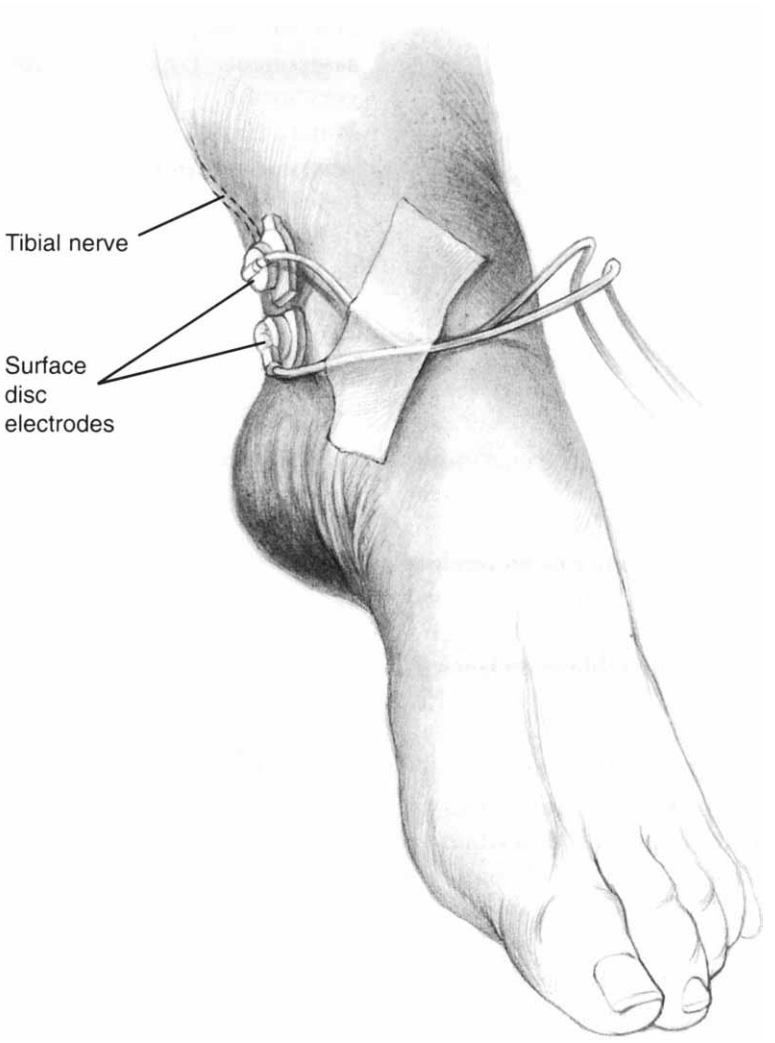
4 (continued) (B) Linear relationship observed between the jugular venous saturation and cerebral metabolic rate for oxygen during cooling and rewarming. This data was from a 55-year-old woman who had replacement of the ascending aorta and arch requiring a 36 minute period of circulatory arrest with normal neurological recovery.



5 Perfusion system used by us to allow for retrograde cerebral perfusion by shunting of oxygenated blood from the femoral arterial line to the venous system. We currently selectively use retrograde perfusion to provide a "washout" of debris near the end of a period of hypothermic circulatory arrest (HCA) for patients in whom the operating surgeon felt would be at high risk due to severe atherosclerotic debris.



6 Position of the cortical and subcortical electrodes for monitoring of SSEP. Disposable subdermal stainless steel needle electrodes (12 mm × 0.4 mm) are placed at the vertex (C2), F2, and C3. A cortical channel is generated with the F2 to C2 electrodes and a subcortical signal is obtained from the F2 to C3 electrodes.



7 Position of the source electrodes for SSEP monitoring. Disposable surface disk electrodes are positioned as shown over the tibial nerve. The evoked potential signals are processed with a Cadwell Quantum 84 SEP generator/stimulator (Cadwell Labs, Kenewick, WA). Averaged signals of 200 potentials cycled alternatively between left and right lower exremities are generated. The averaged signals are interpreted from both waveform analysis and a digitally expressed machine generated latency measurement.

Comments

The use of the jugular bulb oxygen saturation as a marker of the adequacy of cerebral metabolic suppression has been very useful. After introduction of the catheter as outlined previously, the patient is cooled to an esophageal temperature of 15°C while proximal reconstruction is performed. Once the surgeon feels he is within 10 to 15 minutes of completing the proximal reconstruction, the patient is further cooled on bypass with a blood perfusate temperature of 10°C. During this interval, serial jugular bulb samples are taken and the saturation is determined. We feel that a jugular bulb saturation over 95% represents a level of cerebral metabolic suppression adequate to initiate a period of circulatory arrest. We have shown that the cerebral metabolic rate for oxygen at these temperatures in humans is 17.8% ± 19.8% of baseline.[3] In addition to the protection afforded by hypothermia we use 24 hours of perioperative methylprednisolone in patients whose arrest times exceed 30 minutes.

Others have proposed the use of the electroencephalogram (EEG) to determine adequate levels of cerebral metabolic suppression. The use of the EEG is based on the assumption that electrocerebral silence or an isoelectric EEG represents an adequate level of cerebral metabolic suppression.[4] A wide and inconsistent temperature range has been reported to achieve an isoelectric EEG.[4,5] We did some preliminary work with EEG and noted an isoelectric EEG with simultaneous JSATs in the 80% range. Based on these observations, our group does not rely on EEG to monitor the status of cerebral metabolism. With the approach described, a period of circulatory arrest was used in 399 patients since January 1994 with an 8% incidence of permanent neurological dysfunction.

The use of SSEP guided dissection of the descending aorta as described[6] has two potential advantages. The avoidance of back bleeding into an open aorta with the possibility of subsequent "steal" is prevented. The simultaneous, abrupt, severance of multiple input vessels that might result in a sudden drop in the perfusion pressure of the anterior spinal artery is also avoided. Using this approach and postoperative cerebral spinal fluid drainage, we have operated on 179 distal thoracic aorta's since 1994 with a paraplegia rate of 5.6%.

We continue SSEP monitoring in the postoperative period until the patient has recovered from anesthesia and can cooperate reliably with hourly neurological assessment. This postoperative monitoring has proven very useful. Identification of alterations in the postoperative SSEP patterns allow the opportunity to intervene early with the chance of adverting adverse neurological sequale.

Thus, through the use of these easily implemented techniques for central nervous system monitoring during operations on the thoracic aorta, reasonable and consistent neurological outcomes can be obtained.

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From the Department of Cardiothoracic Surgery, The Mount Sinai School of Medicine, New York, NY.

Address reprint requests to Jock N. McCullough, MD, The Mount Sinai Medical Center, Cardiothoracic Surgery, Box 1028, New York, NY 10029.

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